SOME EXPERIMENTS WITH A NEW METHOD OF CLOSING WOUNDS OF THE LARGER ARTERIES.[1]

BY GEORGE EMERSON BREWER, M.D.,

OF NEW YORK,

Professor of Clinical Surgery in the College of Physicians and Surgeons.

THE object of this communication is to report and place on record some experiments undertaken with a view of obtaining some new and simple method of closing accidental wounds of the larger arteries.

The desirability of such a method was forcibly presented to the writer some years ago by an experience which occurred while performing a Bassini operation for the radical cure of inguinal hernia.

The patient was a young man about twenty-eight years of age, who presented himself for treatment of a left inguinal hernia complicated by an undescended testicle. Operation was advised, and the suggestion was readily accepted by the patient.

After removal of the sac of the hernia and the atrophied testicle, while introducing one of the deep sutures of chromicized catgut, a sudden gush of blood occurred from the deeper portion of the wound, which flooded the region and gave rise to a rapidly developing hæmatoma in the surrounding tissues.

It was evident that some deep vessel had been wounded, and an attempt was at once made to locate the injury. Digital pressure on the track of the suture temporarily arrested the bleeding, and the areolar tissue covering the iliac vessels was soon removed, exposing the external iliac artery for about one inch above Poupart's ligament. By transferring the pressure to the proximal portion of the exposed artery, it was seen that the sharp cutting point of the large Hagedorn needle had penetrated the wall of

[1] Read before the New York Surgical Society, October 26, 1904.

the vessel, making a clean-cut, longitudinal wound about one-quarter of an inch in length. As soon as the proximal pressure was removed, a column of blood issued from the wound with such force that it rose fully two feet in the air, a fact which indicated an unusual degree of blood-pressure.

The grave risk of gangrene, amputation, and death, which would necessarily accompany ligation of the external iliac under these circumstances, clearly indicated the advisability of arterial suture and restoration of the blood supply to the limb. As the patient's condition was in every way satisfactory, this was deliberately undertaken with every hope of success.

The wound in the vessel was freely exposed, proximal pressure being maintained, and two or three sutures of fine silk were carefully introduced by means of a small, round, curved needle. These sutures included all the coats of the vessel but the intima, and when drawn together and knotted brought about a satisfactory approximation of the edges of the wound. The proximal pressure was then cautiously removed and the arterial current gradually re-established. At first it seemed that the closure had been successful, but as soon as the full force of the blood-pressure was restored, the stitches began to cut through, and in a few moments the entire wound was reopened by the force of the systolic impulse.

Proximal pressure was again applied and a second attempt made after removing the old sutures. This time the sutures included more of the vessel wall, and the line of approximation was further reinforced by uniting a mass of areolar tissue over it; but the result was the same, the arterial tension was so high that it would have torn out any suture that could have been used, unless the vessel could, at the same time, have been supported by being surrounded with some elastic material which would temporarily diminish its full expansion and the consequent traction on the sutures.

As the arterial wall was by this time so frayed by the torn-out sutures that no further attempt at closure could be undertaken, nothing remained but ligation, which was accordingly performed, and the hernial wound closed in the usual manner.

By rare good fortune, no untoward results followed the ligation. There was scarcely any difference in the temperature of the two limbs, the patient experienced no discomfort, and was

discharged from the hospital, at the end of four weeks, completely cured.

It was during the performance of this operation that the idea of an elastic arterial plaster occurred to the writer.

It was evident that the failure of the sutures to hold was due to the high intra-arterial pressure and the force of the systolic impulse, both of which tended to the separation of the approximated edges.

It seemed at the time that if the vessel could be surrounded by some material which would limit the amount of expansion for even a few hours, and maintain approximation of the edges of the wound, adhesion would occur even without sutures. If so, such a method would also be applicable to many conditions in which suture would be impossible, as in an exceedingly thin or diseased arterial wall, calcification of the media, etc.

The material for such a plaster should be thin, elastic, and capable of maintaining its elasticity for several days after being embedded in the tissues. It must be exceedingly adhesive and capable of thorough sterilization. It seemed to me that, if the adhesive mixture used in the preparation of the well-known zinc oxide plaster could be spread upon thin strips of pure rubber, it might succeed.

After some correspondence with the firm of Johnson & Johnson, of New Brunswick, New Jersey, I had an interview with their chemist, Mr. F. B. Kilmer, who thought that such a material could be made, and that it could be thoroughly sterilized by formaldehyde vapor. After a number of experiments, he finally sent me a sample which seemed perfectly to fulfil the requirements.

Owing, however, to a change in my hospital work and other circumstances which seriously interfered with my plan of animal experimentation, the plaster was laid aside, and nothing was done with it for three or four years, when another similar experience again brought the matter to my attention, and emphasized the necessity of devising some new means of treating these cases.

The second experience occurred while assisting another surgeon perform an amputation of the breast for extensive malignant disease. After cutting off a number of the branches of the axillary artery, and while clearing away a mass of glands and infected areolar tissue surrounding the vessels high up under the coracoid process, he accidentally plunged the point of his scalpel into the axillary artery, inflicting a wound nearly half an inch in length.

In this instance I was able to successfully suture the wounded artery, and the circulation in the extremity was not impaired. Had the vessel wall been diseased, or had the tension been greater, the suture would have failed as in the other patient; and, as most of the anastomosing branches had already been sacrificed, the result of ligation would probably have been disastrous.

Shortly after this last experience, I decided to make a series of animal experiments with the plaster.

These experiments were carried out at the Surgical Laboratory of the College of Physicians and Surgeons, where I was assisted by Dr. J. W. Draper Maury and Mr. Gordon, one of the third-year students, to whom I am also indebted for the postoperative notes on the various animals and for the preparation of the gross specimens.

The following is the technique usually employed: The animal is etherized, the wound area shaved and scrubbed with green soap and hot water, then douched with ether, and a 1 to 1000 solution of bichloride. An incision is then made exposing one of the large arteries, the usual aseptic technique being followed.

As soon as the artery is exposed, it is brought to the surface of the wound and incised with the point of the scalpel. The vessel is then compressed above and below the wound, to prevent excessive hæmorrhage, and the sheath carefully removed. The artery is next cleansed of all blood by the use of a small pledget of gauze moistened with ether. As the ether evaporates, the vessel wall is left clean and dry.

A small strip of the plaster is next passed beneath the vessel, and the two corners held by two small artery clamps in

the hands of an assistant. (Fig. 1.) The strip is then put gently on the stretch and the lower extremity of the strip held by the clamps placed firmly in contact with the vessel, while the upper extremity of the plaster is slowly drawn upward. This causes the vessel to rotate with the plaster until the horizontal edge of the lower extremity of the plaster is on a level with the vessel and firmly adherent to it. (Fig. 2.) The two clamps are then passed over the vessel (Fig. 3) and the plaster kept on the stretch while the operator, with his thumb and forefinger, gently rotates the vessel backward, and at the same time compresses the enveloping plaster until it adheres snugly. The redundant plaster is then removed and the vessel allowed to fall back to its normal position in the wound. (Fig. 4.)

As soon as pressure on the vessel is relieved, the circulation is at once restored, as evidenced by the return of normal pulsations in the distal portion of the artery.

The vessel is then watched for a few moments to see if the plaster remains firmly adherent after pulsation has reappeared. The wound is closed without drainage and a gauze and collodion dressing applied.

The wounds, as a rule, heal kindly, suppuration having occurred in only two instances.

The following is a description of the various experiments and the results:

EXPERIMENT I.—A medium-sized dog was etherized, and the left femoral artery exposed in its lower third. The vessel was not at first recognized, as the writer was not familiar with the bluish color of the arteries in these animals. It was carelessly injured, and later double ligated and divided between the ligatures. Another incision exposed the artery one and one-half inches above. A longitudinal cut was made in the vessel about one-quarter of an inch in length, the plaster applied as described above, and both wounds tightly closed.

EXPERIMENT II.—The right femoral of the same dog was exposed, wounded and treated in the same manner, followed by complete closure of the wound and the application of a cotton and collodion dressing.

The dog recovered from the operation and seemed in his usual spirits the following day. He continued to do well for ten days, when the lower wound on the left thigh became red and inflamed. Two days later an abscess ruptured. On the morning of the thirteenth day the dog was found

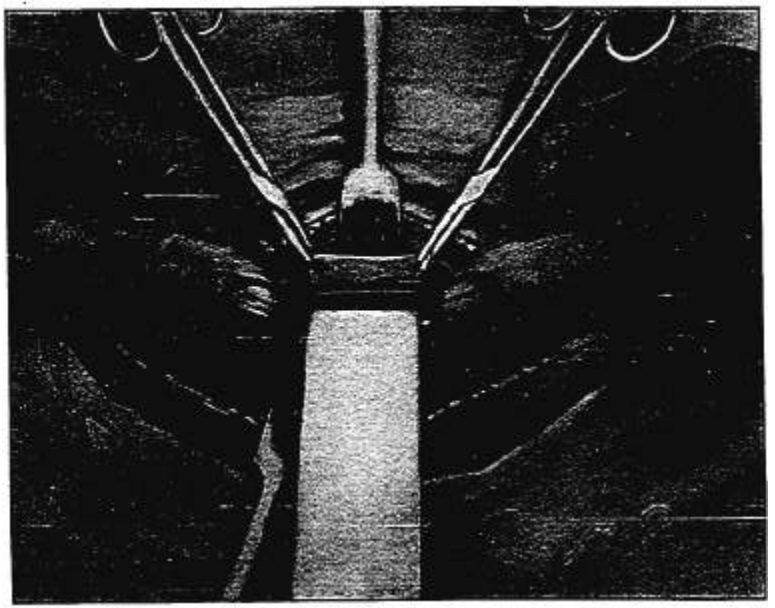

FIG. 1.—The elastic plaster is being drawn through beneath the artery.

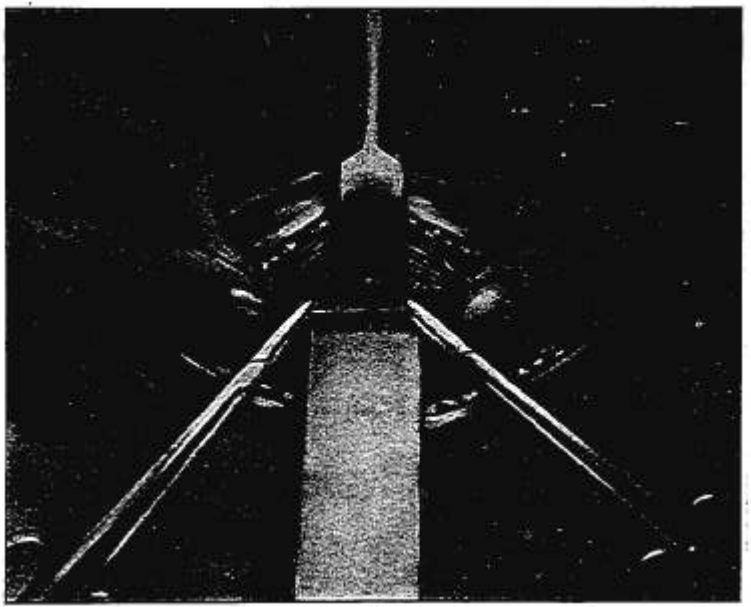

FIG. 2.—The extremity of the adhesive strip is brought in contact with the artery.

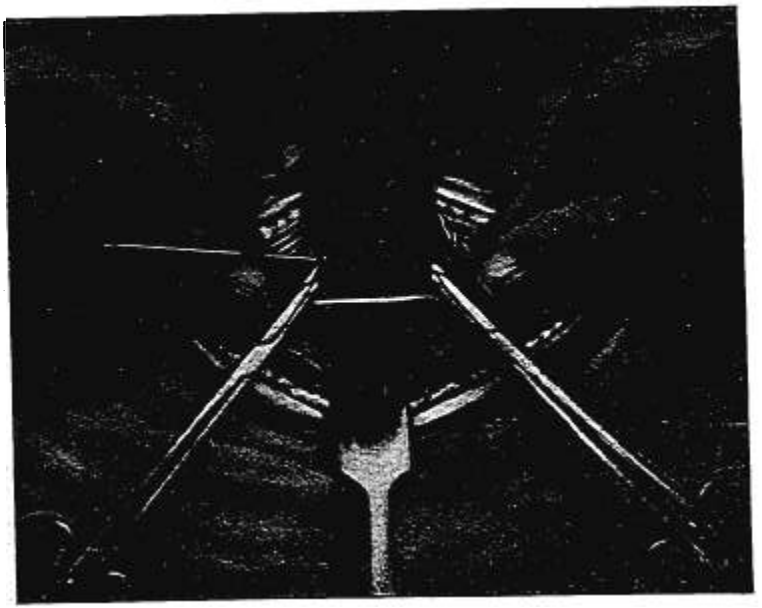

FIG. 3.—The plaster is made to adhere to the artery.

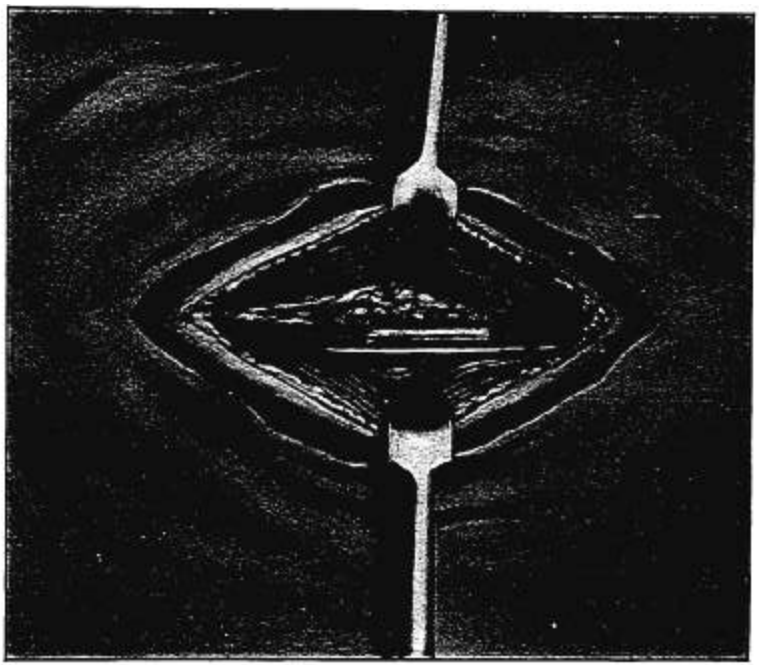

FIG. 4.—The redundant plaster has been removed, and the artery with its collar of plaster allowed to fall back into its normal bed.

dead in his cage, lying in a pool of blood, due to secondary hæmorrhage from the lower infected wound. Autopsy showed the upper wound in the left femoral completely closed and the plaster embedded in the surrounding tissues. The lower portion of the artery near the ligature had sloughed, and the dog had bled to death through the femoral artery, conclusively demonstrating that the vessel had remained patent at the seat of the longitudinal wound. (Microscopic sections of both specimens exhibited.)

Examination of the right femoral artery showed that the plaster had become slightly loosened at one point, and, although the wound in the vessel had healed, the lack of support had resulted in the formation of a saccular aneurism. The lumen was patent throughout.

EXPERIMENT III.—A small fox terrier was etherized. Right common carotid exposed by a three-inch incision, the vessel punctured, and the wound closed with the plaster in the usual manner; circulation re-established, and the cutaneous wound united with a continuous suture of fine silk.

EXPERIMENT IV.—Same animal. The left common carotid was exposed by a separate incision, punctured and closed in the same manner; circulation re-established in the vessel, as evidenced by return pulsations throughout its entire exposed portion. Wound closed and dressed.

The dog recovered from the anæsthesia and showed no sign of discomfort. Two oval swellings appeared over the wounds. There was, however, no tenderness, and the stitches were removed on the fifth day, the swellings having largely subsided. Primary union throughout. Later, the swelling returned over the left wound, and the seventeenth day the wound opened and a small amount of bloody serum was discharged. No pus or redness of the tissues. The wound healed promptly, and the dog continued in excellent health and spirits for over three months, when he was again etherized, both carotids exposed by incision, and on gross inspection no sign of a wound or of the plaster could be detected. Both vessels pulsated normally and equally throughout their entire exposed areas. The vessels were then divided well above the original wounds and the animal allowed to bleed to death. Both specimens were then removed and found to be patent. (Specimens exhibited.)

EXPERIMENT V.—Medium-sized mongrel dog was etherized, and an incision four inches in length made through the left rectus abdominis muscle below the umbilicus. On opening the peritoneal cavity, the intestines were drawn aside and held by sterilized gauze pads, exposing the abdominal aorta. A point was chosen just below the origin of the inferior mesenteric artery, the peritoneum incised, and the areolar tissue and sympathetic fibres removed from the vessel for a distance of one inch.

The artery was then drawn upward and held by the fingers of an assistant. An incision was made with the point of a scalpel through the anterior wall of the vessel, from one-quarter to one-half an inch in length, through which a stream of blood issued with considerable force whenever the proximal pressure was released. The artery was then thoroughly cleansed and dried with gauze pads moistened with ether, the plaster tape applied in the usual manner, and the peritoneum united over the vessel.

Considerable difficulty was experienced in applying the plaster, as it was impossible to raise the artery more than a short distance from the spinal column, owing to the presence of the numerous lumbar branches. The abdominal wound was closed by two layers of suture, and a cotton and collodion dressing applied, which was reinforced by a tight abdominal binder.

At the close of the operation distinct pulsations could be felt in both femorals; and the extremities, which during the operation had become quite cold, soon regained their normal warmth.

No untoward symptoms followed the operation. The dog was up and walked about his cage the following day, and from that time on appeared in good health and spirits.

He lived three months and two weeks, and was then killed for the specimen. On autopsy the vessel at the point of operation was surrounded by a rather dense layer of areolar tissue which completely embedded the plaster. The vessel was thoroughly patent. (Specimens exhibited.)

On all of the animals reported thus far, the first specimen of the plaster furnished by Johnson & Johnson was used. The plaster was exceedingly thin and very adhesive, although its elasticity had been somewhat impaired by the three years it had lain in my desk drawer. That fact was, in the writer's opinion, an advantage, for it could be snugly applied without producing too much pressure on the vessel.

A second specimen of the plaster furnished by Johnson & Johnson for experimental purposes was somewhat heavier and decidedly less adhesive. When applied with the same degree of tension, it caused much greater pressure on the vessel, frequently leading to a narrowing of its lumen, and occasionally to the formation of a clot, even when the vessel wall was not punctured.

EXPERIMENTS VI AND VII.—Same dog as in Experiment V. Both common carotids exposed through a single median incision, sharp longitudinal incision made in each, which was afterwards closed with the heavier plaster. In this instance it was necessary to moisten the adhesive surface of the plaster with ether in order to insure firm adhesion. It was also necessary to hold the plaster in place much longer than in the other experiments. When it was seen that adhesion was firm and that the artery pulsated normally, the wound was closed and dressed in the usual manner. No reaction followed the operation, the wound healed primarily.

Three and one-half months after the operation the dog was killed and the arteries examined. Each was surrounded by a layer of fibrous tis-

sue which completely embedded the plaster. Both arteries were patent. (Specimens exhibited.)

EXPERIMENTS VIII AND IX.—Small dog, median incision. Both carotids explored, incised, and the wound closed with heavy plaster. No reaction. Dog appeared in excellent spirits on day following operation, and continued well until the thirty-fifth day, when he was killed and both arteries removed.

On examination, both arteries contained firm clots; but as they were immediately immersed in a strong solution of formalin after removal and before any examination was made, it is probable, in the absence of any cerebral symptoms, that the clots were of post-mortem origin. (Specimens exhibited.)

EXPERIMENTS X, XI, XII, AND XIII were upon dogs which were at the same time operated upon by another member of the Laboratory Staff, who performed on each a gastro-enterostomy by a new method. Both dogs died of peritonitis, one on the fourth and the other on the fourteenth day. Both carotids were opened and repaired by the heavy plaster.

On autopsy, only one of the carotid wounds was infected. All four arteries, however, were filled with firm clots.

EXPERIMENT XIV was upon a dog also employed for a gastro-enterostomy on the same day. Only one carotid was opened and closed with the plaster. He made a good recovery, but had a very considerable hæmatoma at the site of operation.

As six of the eight experiments with the heavy plaster had upon autopsy shown the vessel to be occluded by a clot, and as none of the animals upon whom the first specimen of plaster was used had presented occluded vessels, it was thought that the trouble was due to the greater degree of pressure exerted on the vessel wall by the heavy plaster, or perhaps to the greater amount of digital compression used to insure firm adhesion.

To verify this, Experiment XV was performed, which consisted simply in exposing the remaining common carotid in the animal used in Experiment XIV, and applying the heavy plaster without wounding the vessel.

On autopsy, both arteries were found to be filled with firm clots, which leaves very little doubt but that the pressure, and not the method, is responsible for the thrombosis.

In the writer's opinion, these experiments demonstrate that, in dogs at least, small wounds of the larger arteries can be successfully treated by the application of an aseptic elastic

plaster. That this plaster should be exceedingly thin, very adhesive, and applied with the minimum of pressure on the vessel wall; and that, if the operation is carried out with perfect aseptic technique, the plaster becomes embedded in the tissues and produces no untoward symptoms.

The writer has had no opportunity of trying this method on the human subject, but would not hesitate to do so if an occasion presented.

FIG. 1.—Family E., photographed July, 1904.

T. E., aged 4½ years; operation at 2½ months.
M. E., aged 2 years; operation at 2 months.
Baby E., aged 5 months; operation at 1 month.

FIG. 2.—Baby E., before operation.

The cranial depressions in the three infants were similar in site and dimensions.